SEFC Contribution No. 464
MARMAP Contribution No. 132

LANDSAT FOLLOW-ON EXPERIMENT - GULF OF MEXICO MENHADEN AND THREAD HERRING RESOURCES INVESTIGATION

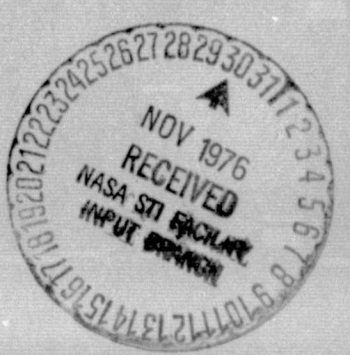
Andrew J. Kemmerer, Kenneth Savastano,
Thomas Leming, and Hillman Holley
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Center
Fisheries Engineering Laboratory
NSTL, Bay Saint Louis, Mississippi 39520

Kenneth Faller
National Aeronautics and Space Administration
Johnson Space Center
Earth Resources Laboratory
Slidell Computer Complex
Slidell, Louisiana 70458

November 1976

Type II Report for Period August 1, 1976 - October 31, 1976

Prepared for
GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland 20071



1. Report No. 6	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle LANDSAT Menhaden and Thread Herring Resources Investigation		5. Report Date November 1976 6. Performing Organization Code
7. Author(s) A. J. Kemmerer, K. J. Savastano, H. J. Holley, T. D. Leming and K. H. Faller*		8. Performing Organization Report No.
9. Performing Organization Name and Address National Oceanic & Atmospheric Administration National Marine Fisheries Service, Southeast Fisheries Center, Technology Division, FEL, NSTL, Bay Saint Louis, Mississippi 39520		10. Work Unit No. 11. Contract or Grant No. S-54114 ID# 20770
12. Sponsoring Agency Name and Address National Aeronautics & Space Administration Goddard Space Flight Center Greenbelt, Maryland 20771		13. Type of Report and Period Covered Type II August 1, 1976 October 31, 1976 14. Sponsoring Agency Code

15. Supplementary Notes
*National Aeronautics and Space Administration
JSC, Earth Resources Laboratory
Slidell Computer Complex, Slidell, Louisiana 70458

16. Abstract

An investigation is being conducted cooperatively by Federal and State Government agencies and private industry to demonstrate the feasibility of using satellite data for enhancing the management and utilization of coastal fishery resources in the northern Gulf of Mexico. Classification algorithms have been developed for LANDSAT MSS data which divide the study areas into high and low probability fishing areas. These classifications are in excess of 80 percent accurate demonstrating the value of satellite derived data for enhancing the harvest and management of coastal fishes in the northern Gulf of Mexico.

A successful two-week field operation was completed in July 1976 to simulate an operational satellite system for providing tactical fishing information and to examine the temporal persistence of high probability fishing areas derived from LANDSAT MSS data. LANDSAT data were processed and classified into high and low probability fishing areas for dissemination to the fishing fleet in less than 21 hours after satellite coverage. Reports from the fishing fleet indicate that the high probability fishing areas produced good fish catches the day following satellite coverage.

17. Key Words (Selected by Author(s))	18. Distribution Statement
Remote Sensing, LANDSAT, Coastal Fishery Resources, Menhaden, Thread Herring, Oceanography	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified		

*For sale by the Clearinghouse for Federal Scientific and Technical Information, Springfield, Virginia 22151.

PREFACE

This progress report covers the investigative period from August 1, 1976, to October 31, 1976. It represents the sixth report since the investigation was formally initiated on April 29, 1975. The first two reports emphasized organization, experimental design and rationale, and field operations. The third, fourth, and fifth summarized analytical processing and analysis, planning, field operations, and analysis of the extension of the LANDSAT Menhaden and Thread Herring Resource Investigation. This report was prepared to give readers a concise overview of the investigation prior to reviewing accomplishments since the last progress report. In addition, it summarizes the status of all data collected in support of the study in the event that someone would like copies for their own use.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

LIST OF ILLUSTRATIONS

TABLE OF CONTENTS (Cont'd)

LIST OF TABLES

ABBREVIATIONS AND SYMBOLS

NASA	National Aeronautics and Space Administration
NMFS	National Marine Fisheries Service
NFMOA	National Fish Meal and Oil Association
LANDSAT-1	Land Satellite (No. 1)
LANDSAT-2	Land Satellite (No. 2)
JSC	Johnson Space Center
ERL	Earth Resources Laboratory
FEL	Fisheries Engineering Laboratory
NOAA	National Oceanic and Atmospheric Administration
NESS	National Environmental Satellite Service
NWS	National Weather Service
AOML	Atlantic Oceanographic and Meteorological Laboratory
GSFC	Goddard Space Flight Center
NSTL	National Space Technology Laboratories
USGS	United States Geological Survey
EROS	Earth Resources Observation Systems
OCSO	Outer Continental Shelf Operations
USCG	United States Coast Guard
NP3A	NASA Medium Altitude Remote Sensing Aircraft
SMS/GOES	Synchronous Meteorological Satellite/Geostationary Operational Environmental Satellite
LLLTV	Low Light Level Television
ISRS	Information Storage and Retrieval Systems
PRT-5	Precision Radiation Thermometer-5
MSS	Multispectral Scanner System
ERTS	Earth Resources Technology Satellite
MFMR	Multifrequency Microwave Radiometer
M^2S	Modular Multispectral Scanner
CCT	Computer Compatible Tape
A/D	Analog to Digital
PCM	Pulse Code Modulated

LANDSAT MENHADEN AND THREAD HERRING RESOURCES INVESTIGATION

1. INTRODUCTION

1.1 REPORTING. This progress report is the sixth in a series under NASA Agreement Number S-54114, ID #20770, sponsored by the NASA Goddard Space Flight Center. It is a type II report covering the investigative period from August 1, 1976, to October 31, 1976.

1.2 OVERVIEW. This investigation is being conducted in two test sites off the coasts of Mississippi and Louisiana. The primary target species is the Gulf menhaden (Brevoortia patronus); the secondary target species is the thread herring (Opisthonema oglinum). Both species form large schools with numbers frequently exceeding one hundred thousand per school. The schools are considered near-surface pelagics which suggests an immediate application of remote sensing techniques. Both species are harvested for conversion into high protein fish meal and oils. Approximately 600,000 tons of menhaden are taken from the Gulf annually representing almost 26 percent of the entire domestic harvest of all fish. While the standing stock of thread herring in the Gulf is believed to exceed that of the menhaden, the catch averages less than 1 percent of the average menhaden landings. The thread herring is truly a latent resource and one which is beginning to receive increased attention from several fishing companies.

The investigation was formally initiated on April 29, 1975. Unofficially, however, the investigation began back as early as November 1974 when a series of meetings began with representatives of the National Fish Meal and Oil Association. These meetings were designed to formulate a plan with the industry for the investigation and in particular to acquire their interest and support.

The investigation was designed to extend over an 18-month period with the first 6 months dedicated primarily to planning and data acquisition (field operations), and the remaining 12 months used for data analysis and report preparation. In July 1976, the LANDSAT Menhaden and Thread Herring Resource Investigation was extended an additional 6 months to pursue two objectives related to the definition and development of satellite remote sensing system for fishery harvest and management. The extension was based on preliminary findings which indicated that water color measured by LANDSAT multispectral scanner (MSS) could be used to predict menhaden distribution in the northern Gulf of Mexico.

This sixth in a series of type II progress reports emphasizes the analytical efforts of the parent investigation and analysis for the LANDSAT Extension.

1.3 OBJECTIVES. The primary objective is to verify the relationship of certain coastal environmental parameters which are observable from aerospace platforms to the

distribution and abundance of Gulf menhaden, a commercially important fish in the northern Gulf of Mexico. A secondary objective is to establish relationships of remotely sensed environmental parameters to a fish with potential commercial importance, thread herring.

Sub-objectives of the multi-phased investigation are:

- Confirm utilization of aerospace data as inputs for a distribution prediction model for adult menhaden in the Mississippi Sound.
- Test utilization of aerospace data as inputs for a distribution prediction model for adult menhaden over the entire season of menhaden availability in the Mississippi Sound.
- Test utilization of aerospace data as inputs for a distribution prediction model for adult menhaden throughout the commercial fishery range in the northern Gulf of Mexico.
- Test utilization of aerospace data as inputs for a distribution prediction model for adult thread herring off the coast of Louisiana.
- Continue development of techniques for the application of remote sensing data to living marine resource assessment and utilization.

Objectives of the contract extension are:

- Simulate the use of an operational satellite system to provide tactical information for the commercial harvest of menhaden.
- Define the persistence of LANDSAT-predicted high probability fishing areas over a 24-hour period.

2. INVESTIGATION PARTICIPANTS

2.1 PRINCIPAL AND CO-INVESTIGATIVE PARTICIPANTS. This experiment is a cooperative venture whose principal participants originate from various Federal agencies and commercial fishing companies. They are as follows:

National Oceanic and Atmospheric Administration (NOAA)
National Marine Fisheries Service (NMFS)
Southeast Fisheries Center
Fisheries Engineering Laboratory
Pascagoula Laboratory

National Aeronautics and Space Administration (NASA)
Earth Resources Laboratory (JSC/ERL)

National Fish Meal and Oil Association (NFMOA)

2.2 ASSOCIATED GROUPS AND AGENCIES. Various groups and agencies who have and are providing assistance in one form or another to the Principal and Co-Investigative elements within the experiment are as follows:

National Oceanic and Atmospheric Administration (NOAA)
- National Marine Fisheries Service (NMFS)
  - Southeast Fisheries Center
    - Miami Laboratory
  - Atlantic Estuarine Fisheries Center
- National Environmental Satellite Service (NESS)
- National Weather Service (NWS)
- Atlantic Oceanographic and Meteorological Laboratory (AOML)

National Aeronautics and Space Administration (NASA)
- Johnson Space Center (JSC)
- Goddard Space Flight Center (GSFC)
- National Space Technology Laboratories (NSTL)

Department of the Interior
- United States Geological Survey (USGS)
  - Earth Resources Observation Systems (EROS)
  - Outer Continental Shelf Operations (OCSO)

United States Coast Guard (USCG)

Mississippi State University

Nicholls State University

Four Oil Companies

3. SUMMARY OF EARLIER REPORTS

As the first five progress reports emphasized organization, responsibilities, experimental rationale, methodology, field operations, and initial analytical efforts, these subjects will only be reviewed in this one. The reader is encouraged to refer to these reports if this summary does not provide enough detail for his particular purpose.

3.1 ORGANIZATION AND RESPONSIBILITIES. The organization consists of a principal investigator who provides overall guidance to the investigation, and the three principal participants (ERL, NFMOA, and SEFC). Responsibilities of ERL include acquisition of aerospace remotely sensed data and conversion of these data into measurements of selected oceanographic parameters. The NFMOA is responsible for the acquisition of fishing data (spotter pilots and vessel captain reports) and review and evaluation of all aspects of the investigation. The SEFC responsibilities include program management and coordination, acquisition of fisheries data, and the development of models for predicting fish distribution from remote measurements of selected oceanographic parameters.

3.2 EXPERIMENTAL RATIONALE AND DESIGN. The rationale is based on the assumption that fish distribution is governed by certain measurable oceanographic parameters. The investigation was designed to identify these parameters and then to determine if they could be remotely measured with sufficient accuracy to predict fish distribution. The parameters considered were limited to those that could be or had the potential of being remotely measured.

3.3 FIELD OPERATIONS. Field operations in 1975 were organized and conducted to satisfy data requirements of the basic units of the experimental design. These operations functioned to provide aerospace remotely sensed data (LANDSAT and aircraft), oceanographic data (research vessels), fish distribution and abundance data (photographic and spotter pilot aircraft), and utilization data (fishing vessels). The primary parameters considered and the platforms from which measurements were made are presented in Figure 3.1.

Two classes of missions were conducted to satisfy the experimental design: main and supplementary. The main missions included all of the platforms shown in Figure 3.1 while the supplementary missions involved only fishing and LANDSAT data. The latter missions were designed to provide data for testing and expanding upon the oceanographic and fishery models developed from data acquired during the main missions.

The two study areas used in the investigation between the superimposed locations of LANDSAT tracks, NP3A, ERL Twin Beech, and NMFS charter aircraft flight lines, oceanographic sampling stations, and oil platforms are shown in Figures 3.2 and 3.3. Both study areas support an active menhaden fishery. Thread herring are primarily found in the offshore portions of the Louisiana study area although infrequently they are caught in the Mississippi Sound.

Figures 3.4 and 3.5 summarize the main and supplementary missions conducted in support of the investigation. The first two main missions in the Louisiana Test Site (Figure 3.4) operated as planned with all platforms acquiring data. The third scheduled mission, however, was aborted due to a reported LANDSAT-1 malfunction. It was rescheduled to coincide with a LANDSAT-2 orbit. The first two Mississippi Sound main missions also operated as planned while the third main mission had to be rescheduled due to inclement weather and unavailability of the NP3A aircraft (Figure 3.5). Unfortunately, even though the main and supplementary missions went smoothly from an operational standpoint, all LANDSAT MSS data from 1975 are of marginal quality due to excessive cloud cover.

The extension of the LANDSAT Menhaden and Thread Herring Resources Investigation (LANDSAT Proposal No. 20770) required field operations in July 1976. The test area for the extension included the Louisiana study area (south of Atchafalaya Bay) used in the parent investigation but extended westward to encompass three adjacent LANDSAT ground tracks (Figure 3.6). LANDSAT overflights occurred on three consecutive days.

Parameter	SURFACE				AIRCRAFT					SATELLITES	
	Fish. Vess. without Observer	Fish. Vess. with Observer	Oceano-graphic Vessel	Oil Platform	NP3A	NASA ERL Aircraft	NFMOA Spotters	NMFS Photo	NMFS LLLTV*	LANDSAT	SMS/GOES
Salinity		X	X	X	X						
Chlorophyll		X	X	X	X*	X				X	
Color		X	X	X	X*	X				X	
Transparency		X	X	X	X*	X				X	
Temperature		X	X	X	X	X					
Water Depth		X	X	X							
Fish School Locations			X			X	X	X	X		
Location of Fish Catches	X	X				X		X			
Meteorology			X				X				X

*Louisiana study area only.

Figure 3.1. Main Day Mission Data Acquisition Platforms and Parameters

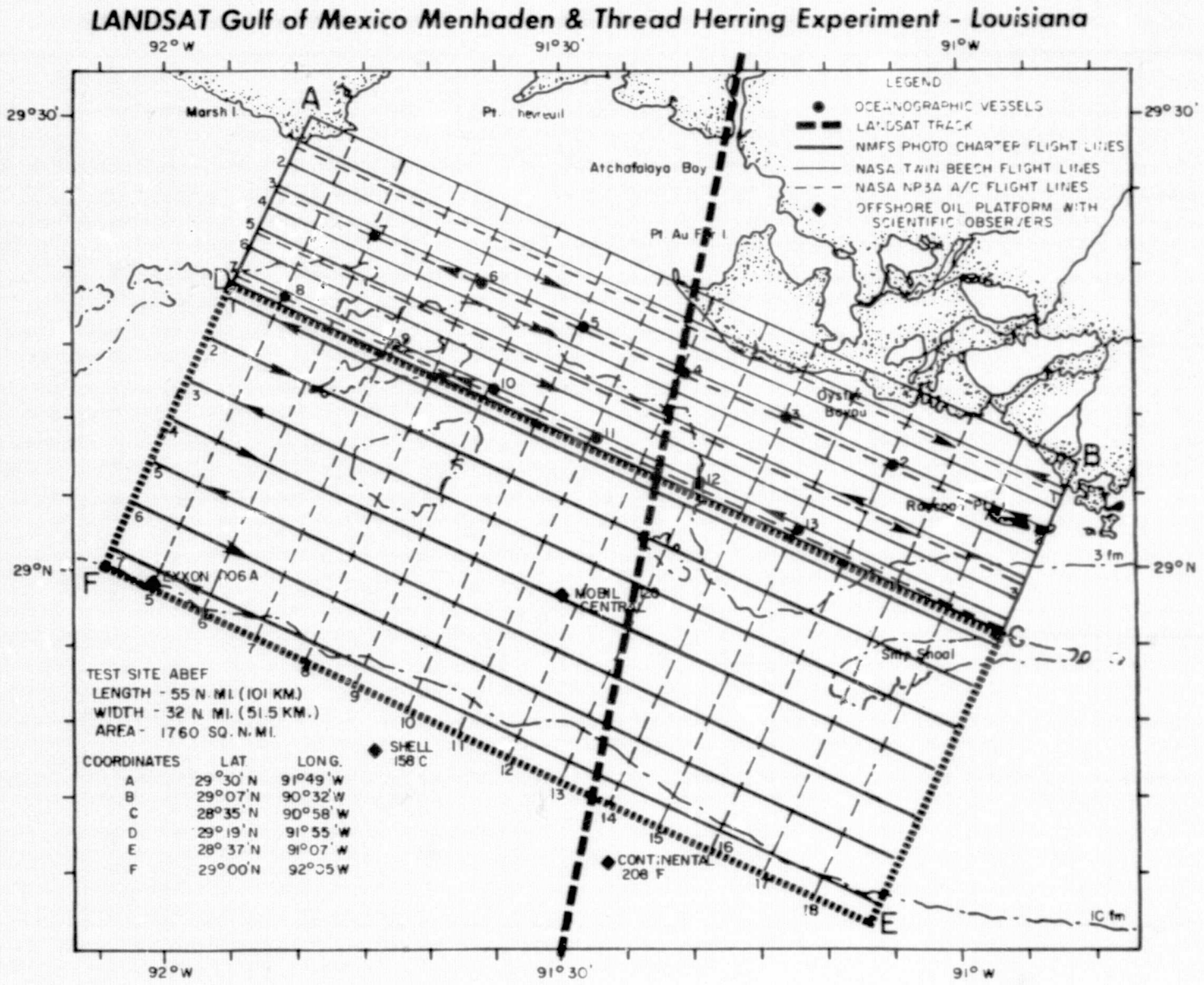


Figure 3.2. Louisiana Study Area Showing the LANDSAT Track, Aircraft Flight Lines, Oceanographic Stations, and Oil Platform Locations

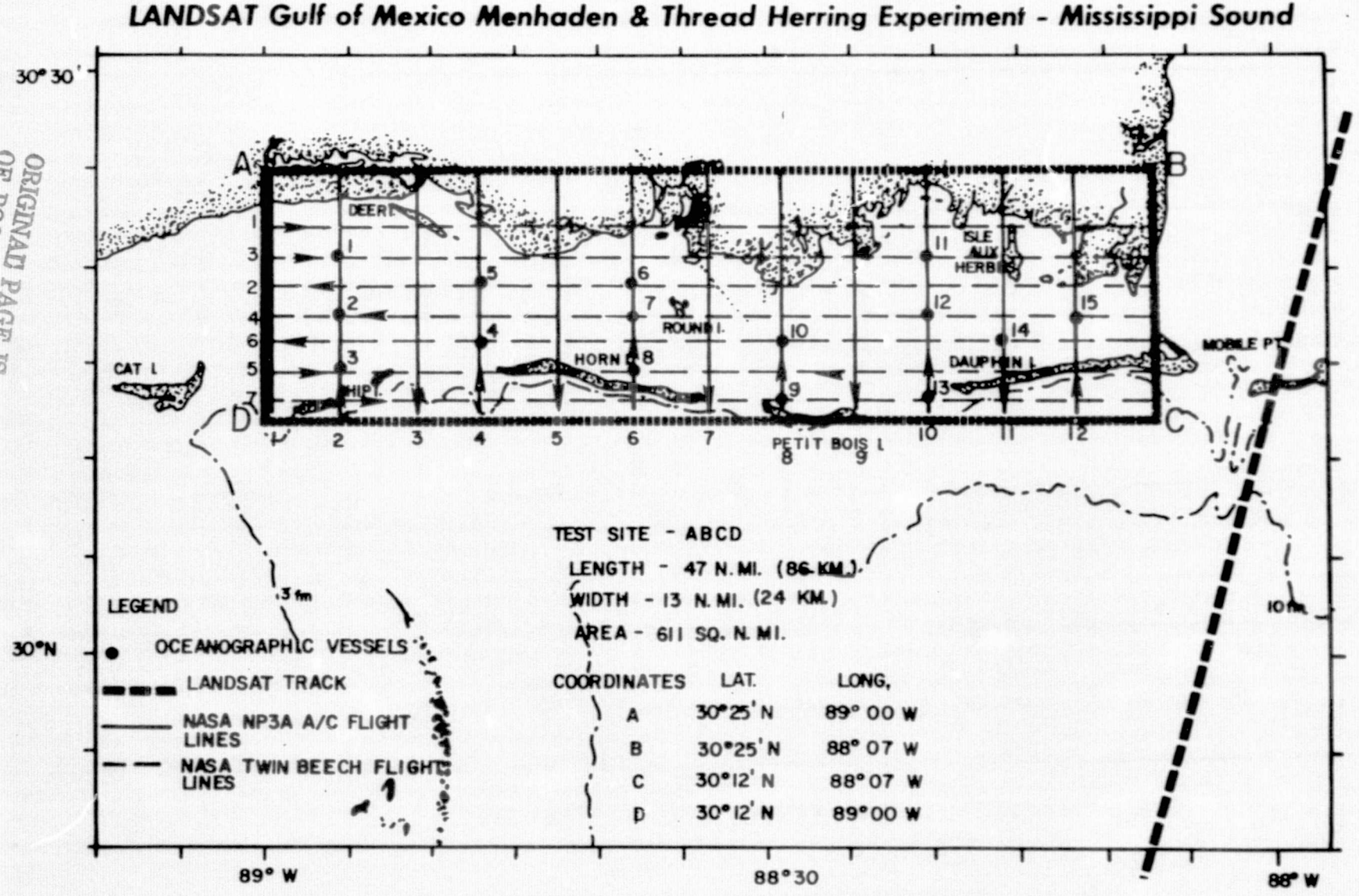


Figure 3.3. Mississippi Sound Study Area Showing the LANDSAT Track, Aircraft Flight Lines, and Oceanographic Stations

SUMMARY OF LOUISIANA LANDSAT MISSIONS (1975)

PLATFORM	MISSION / DATE	MAIN APR 25	MAIN MAY 13	SUPPLE-MENTARY JUN 18	ABORTED MAIN [1] JUL 24	SUPPLE-MENTARY AUG 11	RESCHED-ULED MAIN AUG 20	SUPPLE-MENTARY AUG 29	SUPPLE-MENTARY SEP 16
FISHING VESSELS		X	X	X	X	X	X	X	X
SPOTTER AIRCRAFT		X	X	X	X	X	X	X	X
FISHING VESSEL OBSERVERS		X	X		X		X		
RESEARCH VESSELS		X	X				X		
OIL PLATFORMS		X	X				X		
ERL AIRCRAFT		X	X				X		
NP3A AIRCRAFT		X	X				X		
PHOTO-GRAPHIC AIRCRAFT		X	X				X		
LANDSAT I		X	X	X	X	X	X [2]	X	X

1 Mission aborted due to mechanical failure reported aboard LANDSAT I

2 LANDSAT II

Figure 3.4. Summary of Louisiana Test Site Missions (1975)

SUMMARY OF MISSISSIPPI SOUND LANDSAT MISSIONS (1975)

PLATFORM	MISSION DATE	MAIN MAY 2	MAIN MAY 20	SUPPLE-MENTARY JUN 25	ABORTED MAIN 1 JUL 31	SUPPLE-MENTARY AUG 18	MAIN[2] SEP 5	SUPPLE-MENTARY SEP 23
FISHING VESSELS		X	X	X	X	X	X	X
SPOTTER AIRCRAFT		X	X	X	X	X	X	X
FISHING VESSEL OBSERVERS		X	X		X		X	
RESEARCH VESSELS		X	X				X	
ERL AIRCRAFT		X	X					
NP3A AIRCRAFT		X	X				X	
LANDSAT II		X	X	X	X	X	X	X

1 Mission aborted due to inclement weather and unavailability of NP3A.

2 ERL Aircraft unable to complete mission due to inclement weather and mechanical failure.

Figure 3.5. Summary of Mississippi Sound Missions (1975)

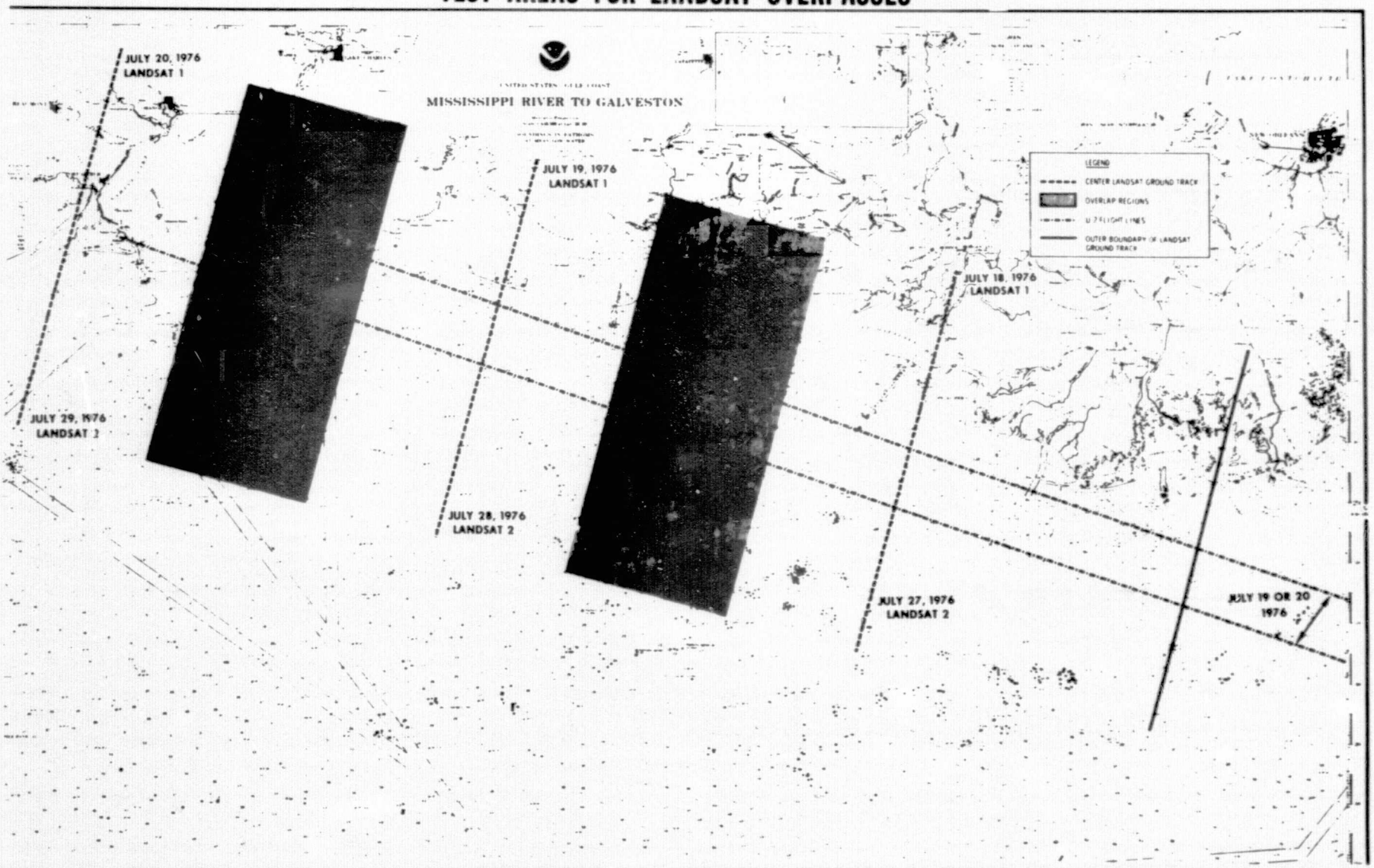


Figure 3.6. Test Areas for LANDSAT Overpasses

Figure 3.7 presents a summary of the planned Louisiana LANDSAT Mission (1976). The survey is presented by platform and day. Fishing vessels without observers were to acquire set information (time, location, species, and number) on 5 days of the field operations. The fishing vessels with scientific observers aboard were scheduled to acquire fishing and oceanographic data everyday (fishing generally does not occur on Saturday and Sunday). These latter vessels also were equipped with LORAN-C navigation system for improved location information. Spotter aircraft were scheduled to collect fish location, identification, and abundance information on three days of each fishing week. One aircraft was equipped with a LORAN-C unit. Two oceanographic vessels were used to collect sea truth information on the 19th or 20th of July.

A summary of data actually acquired during the two-week operation period is given in Figure 3.8. While not all of the platforms provided data as planned for a variety of reasons, enough redundancy had been constructed in the plan to ensure a successful operation. Sufficient cloud-free areas of satellite information are available for analysis.

While the U-2 ocean scanner flight was not a contractual part of the extension, it is reported on here for completeness. Both flight lines were flown during the morning of July 20, 1976. The pilot reported 60 percent cloud cover over the eastern portion of the flight lines and about 20 percent over the western end. Color scanner data have been sent to Goddard for processing and delivery was received in September 1976. These data will be used to optimize spectral regions and bandwidths for fishery applications.

3.4 DATA PROCESSING AND ANALYSIS. Emphasis for data processing has been given to reviewing available data for quality determinations and preparing it for insertion into a single LANDSAT data management system. The single system was developed to insure a complete data file for analytical purposes by current as well as future investigators.

Analytical emphasis initially was given to the sea truth data collected from fishing and research vessels. The objectives of these analyses were to identify those parameters and analytical techniques which offered the greatest potential for satisfying the objectives of the investigation. The analytical rationale was to compare oceanographic measurements at sites of menhaden capture with those taken from the research vessels over time and between test sites. This was done to determine if menhaden appeared to prefer a relatively constant range of environmental conditions. The assumption was that those parameters remaining relatively constant in magnitude, but demonstrating differences from those measured from the research vessels could be used to predict fish distribution.

The parameters which appeared to have significant direct effects on menhaden distribution are water turbidity (secchi disc) and color (Forel-Ule). Surface water temperature and salinity appeared to have little direct effect. Chlorophyll-a also did not appear to be a very good indicator of menhaden distribution.

SUMMARY OF PLANNED LOUISIANA LANDSAT MISSION (1976)

PLATFORM		MAIN	DATE (JULY 1976)							MAIN [2]			
	18 SUN	19 MON	20 TUE	21 WED	22 THU	23 FRI	24 SAT	25 SUN	26 MON	27 TUE	28 WED	29 THU	30 FRI
FISHING VESSELS		X	X							X	X	X	
FISHING VESSELS WITH OBSERVERS (8)		X	X	X	X	X			X	X	X	X	X
SPOTTER AIRCRAFT	X	X	X							X	X	X	
SPOTTER AIRCRAFT WITH LORAN-C	X	X	X							X	X	X	
RESEARCH VESSELS (2)		X	X										
U-2 AIRCRAFT		X	X[1]										
LANDSAT I	X	X	X										
LANDSAT II										X	X	X	

1. Planned as back-up mission
2. Rescheduled as supplementary upon successful July 19 mission

Figure 3.7. Summary of Louisiana Test Site Missions (1976)

SUMMARY OF ACQUIRED DATA FOR LOUISIANA LANDSAT MISSION (1976)

PLATFORM		MAIN	DATE (JULY 1976)										
	18 SUN	19 MON	20 TUE	21 WED	22 THU	23 FRI	24 SAT	25 SUN	26 MON	27 TUE	28 WED	29 THU	30 FRI
FISHING VESSELS		X	X	X	X	X							
FISHING VESSELS WITH OBSERVERS (8)		X	X	X	X	X			X	X	X	X	X
SPOTTER AIRCRAFT	X	X	X	X						X			
SPOTTER AIRCRAFT WITH LORAN-C		X									X		
RESEARCH VESSELS (2)			X										
U-2 AIRCRAFT			X										
LANDSAT I	X	X	X										
LANDSAT II										X	X	X	

Figure 3.8. Summary of Acquired Data for Louisiana Test Site Missions (1976)

Remotely sensed salinity data from April 25, May 13, May 20, August 20 and September 5, 1975, were processed to listings of sea surface salinity at half mile intervals along flight lines. A comparison of remote measurements with surface truth measurements for the above missions has been completed. Remotely sensed salinity from May 2, 1975, will not be processed due to unresolvable data problems. Remotely sensed temperature data from all six missions were processed to listings of sea surface temperature.

Correlation and multiple regression analyses were applied to surface truth data collected by scientific observers aboard the commercial fishing vessels. The surface truth data for temperature, secchi disc transparency, Forel-Ule color, salinity, and chlorophyll-a were extracted for each day of the six main and the two aborted main mission periods (July 24 [Louisiana] and July 31 [Mississippi]). Correlation coefficients for each of the parameters by date were completed using the presence or absence of fish (i.e., 0 = no fish and 1 = fish) as the dependent variable. Analysis of the correlation coefficients of each parameter from data set to data set showed an inconsistency in both magnitude and range. Step-wise multiple regression models developed using these data sets were not accurate in predicting no fish areas using test data. The order of selection of the parameters (secchi disc, salinity, temperatures, chlorophyll-a and Forel-Ule color) was not consistent with respect to previous analyses. From the data analyzed, it is evident that collection of true no-fish data samples cannot be done from commercial menhaden fishing vessels under normal fishing conditions. This information was utilized during the July 1976 field operation, during which all no-fish oceanographic sampling was eliminated.

The computer generated composite point plots for all main missions (three in Mississippi Sound and three off Louisiana) for surface water temperature Forel-Ule color, secchi disc transparency, salinity, chlorophyll-a and remotely sensed temperature and salinity. Surface truth remotely sensed data, and fisheries data sets were developed for the three missions; April 25, May 13, and May, 20, 1975; from contour maps. Correlation and multiple regression analysis were applied to the data from all three missions. Water color as inferred from Forel-Ule color measurements generally correlated well with menhaden distribution. Regression model correlation coefficients averaged about 0.55 for the three missions indicating fairly low levels of statistical precision. The models were about 75 percent accurate in predicting menhaden distribution.

Four distinct methods were applied to LANDSAT MSS data for classification of the study areas into high and low probability fishing areas. These methods include parallelepiped, multiple regression, maximum likelihood and discriminant function classifications. In addition, LANDSAT MSS and surface truth data were combined into a single predictive algorithm.

The parallelepiped classifier worked well on the May 20 and June 25 (Mississippi Sound) MSS data, but performed poorly for the July 24 (Louisiana) MSS data set. Multiple regression models were developed from MSS spectral data for May 20,

June 25, and July 24. The precision of the resultant models was reasonably good with correlation coefficients ranging from 0.736 to 0.894. All were significant at confidence levels exceeding 99 percent. Results from classification of training samples indicate accuracies of approximately 90 percent. Discriminant function models were developed from MSS spectral data from June 25 and July 24. Training sample classification accuracy was approximately 90 percent. Data from July 24 were processed with the maximum likelihood classifier (ELL TAB) and results compared favorably to those of the discriminant function classifier. A simple likelihood classifier was used to classify the July 24 data with almost identical results to those provided by ELL TAB. This classifier was also used for processing July 19, 1976, data for the rapid turnaround experiment. Again, the results were similar to the classification achieved with the discriminant function technique.

Correlation and multiple regression analyses were performed using a combination of LANDSAT and surface truth data from May 20. MSS data correlated more precisely with menhaden distribution than the classical oceanographic parameters such as temperature, Forel-Ule color, salinity, and secchi disc transparency. A multiple regression model was developed from the two data sets. A slight improvement in model precision was noted over an earlier model developed solely from MSS data, but not enough to warrant the additional parameters.

An effort was made to simulate SMS-GOES broad band visible spectrum data from LANDSAT MSS data to be used to develop menhaden distribution prediction models. The rationale behind the GOES simulation was to determine if this system might be considered as an operational tool for providing tactical fishing information. GOES provides repeat coverage every 30 minutes compared to the 18-day LANDSAT coverage cycle. Preprocessed LANDSAT data for each spectral band and the sum of bands 4 and 5 radiance values were compared to with and without menhaden sample areas through correlation analysis. The sum of the two bands was used to approximate the spectral response of the GOES system for comparison with LANDSAT. It should be understood, however, that the summation does not truly simulate GOES data; it only provides a rough approximation. This is due to a number of factors including (1) LANDSAT bands 4 and 5 do not cover the exact spectral range of GOES, (2) spectral response curves were not used to adjust the radiance values before summing, and (3) spatial resolution of the LANDSAT was degraded only to about 1/3 of that provided by GOES. Multiple regression models were developed from MSS spectral data for three missions (May 20, June 25, and July 24, 1975) using all four bands and the sum of bands 4 and 5. The regression models were used to classify LANDSAT data into low and high probability fishing areas for each of the respective missions. The regression models using the sum of bands 4 and 5 compared favorably with the four band models. The models were about 85 percent accurate in classifying the study areas into high and low probability menhaden areas. Accuracy was computed from the sample areas used to develop the models.

The extension of the LANDSAT Menhaden and Thread Herring Resources Investigation (LANDSAT Proposal No. 20770) pursued two objectives related to the definition and development of a satellite remote sensing system for fishery harvest and management. The extension was based on preliminary findings from the parent investigation which indicate that water color measured with the LANDSAT multispectral

scanner (MSS) could be used to predict menhaden distribution in the northern Gulf of Mexico.

Current satellite systems capable of providing the multispectral data are not designed for real-time applications, and it is difficult to assess the significance of the resource distribution prediction without near real-time dissemination of the distribution data to the field. Consequently, special arrangements were made with GSFC to pre-process LANDSAT multispectral data immediately upon receipt from the satellite and supply it to the ERL and FEL for near real-time analysis. Calibration data were provided on the same basis from industry spotter pilots working in the study area and scientific observers placed on commercial menhaden vessels by FEL.

The day prior to the principal satellite pass (July 19, 1976), scientific observers boarded eight menhaden vessels at ports across western and central Louisiana. The satellite passed over west-central Louisiana, covering the area from Sabine to Marsh Island. Two menhaden spotters were made available to the investigation the day before the main pass to determine the prime areas for the study and to provide precise fish school locations in the zone of overlap between that day's LANDSAT pass and the pass of the principal day. An abundance of fish were present in the study area. The satellite passed over the area at 10:25:50 CDT.

Representatives from FEL and NFMOA were at GSFC on July 19, 1976, to review the satellite data shortly after reception. Information pertaining to fish school locations was telephoned to them at about 1100 hours (CDT) so that they could evaluate the significance of clouds in the coverage area. The LANDSAT data were received at GSFC at 1027 CDT. The early fishing reports placed most of the school locations in the easternmost portion of the image which was heavily cloud covered. A decision to go was reached at about 1330 CDT. Two complete sets of CCT's were delivered to the FEL representative at 1500 CDT. The tapes were then hand-carried via commercial airliner to Slidell. Arrival was at 2045 CDT. By the time of the arrival of the tapes, locations of fish schools set on by the fleet or identified by the spotter pilots had been plotted on navigation charts. Locations were made using LORAN-C or VHF omnidirectional VOR navigation.

Computer classifications were complete by 0715 CDT July 20. At this time they were viewed and high probability fishing areas were marked on navigation charts. These results were transmitted to the commercial fleet. The commercial fleet reported that fish were concentrated in the high probability areas indicated by the analysis of the satellite data, and that they were having one of the best days of the season to date. A quantitative verification of this opinion was attempted by plotting the location of menhaden capture and observation on the prediction chart (also shown in Figure 4.7). If the school location areas which could not be classified due to cloud cover are ignored, one can see that the majority of the observations were in or adjacent to the high probability areas predicted from LANDSAT data.

4. ACCOMPLISHMENTS

This section will describe progress made during the last three months in data processing, data analysis, and the extension of the investigation to cover simulation of

the use of an operational satellite system to provide tactical information for the commercial harvest of menhaden.

4.1 DATA PROCESSING. The status of data flow is shown in Figures 4.1 through 4.6.

Contour maps have been developed for the May 2, 1975, mission for surface water temperature, Forel-Ule color, secchi disc transparency, salinity, chlorophyll-a, remotely sensed salinity, and remotely sensed temperature. Data sets for the seven parameters as well as the dependent parameter (menhaden distribution) have been prepared utilizing the contour maps. The data sets will be used in correlation and multiple, regression/discriminant function analyses.

Work has been initiated on the second objective of the contract extension which was to define the persistence of LANDSAT predictive high probability fishing areas over a 24 hour period. LANDSAT tapes for July 27, 28, and 29, 1976, have been received and reviewed. The data is of excellent quality. The tapes have been reformatted and control points have been selected for grid construction for the July 27 and July 28, 1976, tapes. The overlap region of approximately 25 percent of the image from both days will be classified from each day and then analyzed for differences.

4.2 DATA ANALYSIS (LANDSAT Menhaden and Thread Herring Resource Investigation Extension). After the operational system simulation was completed, a check of the data collected revealed that the LORAN-C unit aboard the spotter aircraft gave faulty position readings. A check of readings at the airport before take-off, and after landing showed that the unit was producing readings on the SS7-W Jupiter, Florida, line that were consistently 10 microseconds low. Since some of these locations were used for training sample selection, corrections were made and new training samples were selected. Table 4.1 gives the original and corrected positions and the associated training sample radiance values. The corrected positions are about five nautical miles closer to shore than the ones used during the simulation. Statistics were recomputed and a new discriminant function classifier was applied to the image. Figure 4.7 shows the predicted high probability fishing areas for July 20, 1976, given to the fishermen on July 20, 1976. Figure 4.8 shows the predicted high probability fishing areas for July 20, 1976, using July 19, 1976, LANDSAT data with the corrected menhaden locations. Neither of the diagram classification areas are precise because they were made by hand from classified images displayed on portable image display system (PIDS). Fish locations have a certain level of error also, because they are superimposed from one set of maps to the diagram by hand. Precise images from the computer containing the classified areas with fish schools located by scan line and element will be developed and displayed in future reports. As can be seen from Figure 4.7 and 4.8, the second classification is more concise and closer inshore. More of the schools of fish inshore were classified correctly while some of the offshore schools were missed. In general the second classification appears to be the better of the two. Comparison of the computed generation classifications will be the best test in determining which classification is better.

4.3 FUTURE PLANS. Emphasis for the next few months will be given to the analysis of the menhaden fishing distribution data and environmental/remotely sensed data for the remaining 1975 missions. Analysis of 1976 LANDSAT data from overlap regions

LANDSAT DATA FLOW

X Completed
▽ Terminated

Mission No. 1
Date 25 April
Site Louisiana

SURFACE TRUTH

Platform	Data Type	Data Acq.	Data Rec.	Data Veri.	Data Trans.	Data Veri.	Key Punched	Data Ret.	Data Veri.	Data to Comp.	Data Ret.	Data Anal.
Fishing Vessel	Fish Data	X	X	X	X	X	X	X	X	X	X	X
	Oceano. Data	X	X	X	X	X	X	X	X	X	X	X
Spotter Pilot	Fish Data	X	X	X	X	X	X	X	X	X	X	X
Oceano. Vessel	Oceano. Data	X	X	X	X	X	X	X	X	X	X	X
Oil Platform	Oceano. Data	X	X	X	X	X	X	X	X	X	X	X
NMFS A/C Charter (photo)	Fish Loc. Data	X	X	X	▽							
NASA Twin Beech	Fish Photo Data, KC1B	X	X	X	X	X	X	▽				

REMOTE SENSING

Platform	Data Type	Data Acq.	Data Rec.	Quick Look	A/D, Decom. or Refo.	Raw Product	Correl. w/ Surf. Truth	Final Data Prod.	Sample Extract.	Data to Comp.	Data Ret.	Data Anal.
NASA Twin Beech	RS-18	X	X	X	▽							
	PRT-5	No										
NASA NP3A A/C	MFMR	X	X	X	X	X	X	X	X	X		
	M^2S	Yes	X	X	▽							
	PRT-5	X	X	X	X	X	X	X	X	X		
LANDSAT	Imagery	X	X	X	NA	X	▽					
	CCT	X	X	X	X	X	▽					

Figure 4.1. Platform and Data Flow Status Summary for the April 25, 1975, Louisiana Main Day Mission

LANDSAT DATA FLOW

Mission No. 2
Date 2 May
Site Mississippi Sound

X Completed
▽ Terminated

SURFACE TRUTH

Platform	Data Type	Data Acq.	Data Rec.	Data Veri.	Data Trans.	Data Veri.	Key Punched	Data Ret.	Data Veri.	Data to Comp.	Data Ret.	Data Anal.
Fishing Vessel	Fish Data	X	X	X	X	X	X	X	X	X	X	
	Oceano. Data	X	X	X	X	X	X	X	X	X	X	
Spotter Pilot	Fish Data	X	X	X	X	X	X	X	X	X	X	
Oceano. Vessel	Oceano. Data	X	X	X	X	X	X	X	X	X	X	
NASA Twin Beech	Fish Photo Data, KC1B	X	X	X	X	X	▽					

REMOTE SENSING

Platform	Data Type	Data Acq.	Data Rec.	Quick Look	A/D, Decom. or Refor	Raw Product	Correl. w/ Surf. Truth	Final Data Prod.	Sample Extract	Data to Comp.	Data Ret.	Data Anal.
NASA Twin Beech	RS-18	X	X	X	Partial	X	▽					
	PRT-5	X	X	X	X	X	X	X	X	X	X	
NASA NP3A A/C	MFMR	X	X	X	X	X	X	X	▽			
	M^2S	No										
	PRT-5	X	X	X	X	X	X	X	▽			
LANDSAT	Imagery	X	X	X	NA	X	▽					
	CCT	X	Not Ordered									

Figure 4.2. Platform and Data Flow Status Summary for the May 2, 1975, Mississippi Sound Main Day Mission

LANDSAT DATA FLOW

X Completed
▽ Terminated

Mission No. 3
Date 13 May
Site Louisiana

SURFACE TRUTH

Platform	Data Type	Data Acq.	Data Rec.	Data Veri.	Data Trans.	Data Veri.	Key Punched	Data Ret.	Data Veri.	Data to Comp.	Data Ret.	Data Anal.
Fishing Vessel	Fish Data	X	X	X	X	X	X	X	X	X	X	X
	Oceano. Data	X	X	X	X	X	X	X	X	X	X	X
Spotter Pilot	Fish Data	X	X	X	X	X	X	X	X	X	X	X
Oceano. Vessel	Oceano. Data	X	X	X	X	X	X	X	X	X	X	X
Oil Platform	Oceano. Data	X	X	X	X	X	X	X	X	X	X	X
NMFS A/C Charter (photo)	Fish Loc. Data	X	X	X	▽							
NASA Twin Beech	Fish Photo Data, KC1B	X	X	X	X	X	▽					

REMOTE SENSING

Platform	Data Type	Data Acq.	Data Rec.	Quick Look	A/D, Decom. or Refo.	Raw Product	Correl. w/ Surf. Truth	Final Data Prod.	Sample Extract.	Data to Comp.	Data Ret.	Data Anal.
NASA Twin Beech	RS-18	X	X	X	▽							
	PRT-5	X	X	X	X	X	X	X	X	X	X	
NASA NP3A A/C	MFMR	X	X	X	X	X	X	X	X	X		
	M^2S	X	X	X	▽							
	PRT-5	X		X	X	X	X	X	▽			
LANDSAT	Imagery	X	X	X	NA	X	▽					
	CCT	X	X	X	X	X	▽					

Figure 4.3. Platform and Data Flow Status Summary for the May 13, 1975, Louisiana Main Day Mission

LANDSAT DATA FLOW

X Completed
▽ Terminated

Mission No. 4
Date 20 May
Site Mississippi Sound

SURFACE TRUTH

Platform	Data Type	Data Acq.	Data Rec.	Data Veri.	Data Trans.	Data Veri.	Key Punched	Data Ret.	Data Veri.	Data to Comp.	Data Ret.	Data Anal.
Fishing Vessel	Fish Data	X	X	X	X	X	X	X	X	X	X	X
	Oceano. Data	X	X	X	X	X	X	X	X	X	X	X
Spotter Pilot	Fish Data	X	X	X	X	X	X	X	X	X	X	X
Oceano. Vessel	Oceano. Data	X	X	X	X	X	X	X	X	X	X	X
NASA Twin Beech	Fish Photo Data, KC1B	X	X	X	X	X	X	X	X	▽	▽	X

REMOTE SENSING

Platform	Data Type	Data Acq.	Data Rec.	Quick Look	A/D, Decom. or Refor	Raw Product	Correl. w/ Surf. Truth	Final Data Prod.	Sample Extract	Data to Comp.	Data Ret.	Data Anal.
NASA Twin Beech	RS-18	X	X	X	X	X	▽					
	PRT-5	X	X	X	X	X	X	X	X	X	X	X
NASA NP3A A/C	MFMR	X	X	X	X	X	X	X	X	X	X	X
	M^2S	No										
	PRT-5	X	X	X	X	X	X	X	▽			
LANDSAT	Imagery	X	X	X	NA	X	X	X	X	NA	NA	X
	CCT	X	X	X	X	X	X	X	X	X	X	X

Figure 4.4. Platform and Data Flow Status Summary for the May 20, 1975, Mississippi Sound Main Day Mission

LANDSAT DATA FLOW

Mission No. 5
Date 20 August
Site Louisiana

X Completed
▽ Terminated

SURFACE TRUTH

Platform	Data Type	Data Acq.	Data Rec.	Data Veri.	Data Trans.	Data Veri.	Key Punched	Data Ret.	Data Veri.	Data to Comp.	Data Ret.	Data Anal.
Fishing Vessel	Fish Data	X	X	X	X	X	X	X	X	X	X	
	Oceano. Data	X	X	X	X	X	X	X	X	X	X	
Spotter Pilot	Fish Data	X	X	X	X	X	X	X	X	X	X	
Oceano. Vessel	Oceano. Data	X	X	X	X	X	X	X	X	X	X	
Oil Platform	Oceano. Data	X	X	X	X	X	X	X	X	X	X	
NMFS A/C Charter (photo)	Fish Loc. Data	X	X	X	▽							
NASA Twin Beech	Fish Photo Data, KC1B	X	X	X	▽							

REMOTE SENSING

Platform	Data Type	Data Acq.	Data Rec.	Quick Look	A/D, Decom. or Refo.	Raw Product	Correl. w/ Surf. Truth	Final Data Prod.	Sample Extract.	Data to Comp.	Data Ret.	Data Anal.
NASA Twin Beech	RS-18	X	X	X	▽							
	PRT-5	X	X	X	X	X	X	X	X	X	X	
NASA NP3A A/C	MFMR	X	X	X	X	X	X	X	X			
	M^2S	X	X	X	▽							
	PRT-5	X	X	X	X	X	X	X	▽			
LANDSAT	Imagery	X	X	X	NA	X	▽					
	CCT	X	X	X	X	X	▽					

Figure 4.5. Platform and Data Flow Status Summary for the August 20, 1975, Louisiana Test Site Main Day Mission

LANDSAT DATA FLOW

Mission No. 6
Date 5 September
Site Mississippi Sound

X Completed
▽ Terminated

SURFACE TRUTH

Platform	Data Type	Data Acq.	Data Rec.	Data Veri.	Data Trans.	Data Veri.	Key Punched	Data Ret.	Data Veri.	Data to Comp.	Data Ret.	Data Anal.
Fishing Vessel	Fish Data	X	X	X	X	X	X	X	X	X	X	
	Oceano. Data	X	X	X	X	X	X	X	X	X	X	
Spotter Pilot	Fish Data	X	X	X	X	X	X	X	X	X	X	
Oceano. Vessel	Oceano. Data	X	X	X	X	X	X	X	X	X	X	
NASA Twin Beech	Fish Photo Data, KC1B	X	X									

REMOTE SENSING

Platform	Data Type	Data Acq.	Data Rec.	Quick Look	A/D, Decom. or Refor	Raw Product	Correl. w/ Surf. Truth	Final Data Prod.	Sample Extract	Data to Comp.	Data Ret.	Data Anal.
NASA Twin Beech	RS-18	No										
	PRT-5	No										
NASA NP3A A/C	MFMR	X	X	X	X	X	X	X	X			
	M^2S	No										
	PRT-5	X	X	X	X	X	X	X	X			
LANDSAT	Imagery	X	X	X	▽							
	CCT	X	not ordered									

Figure 4.6. Platform and Data Flow Status for the September 5, 1975, Mississippi Sound Main Day Mission

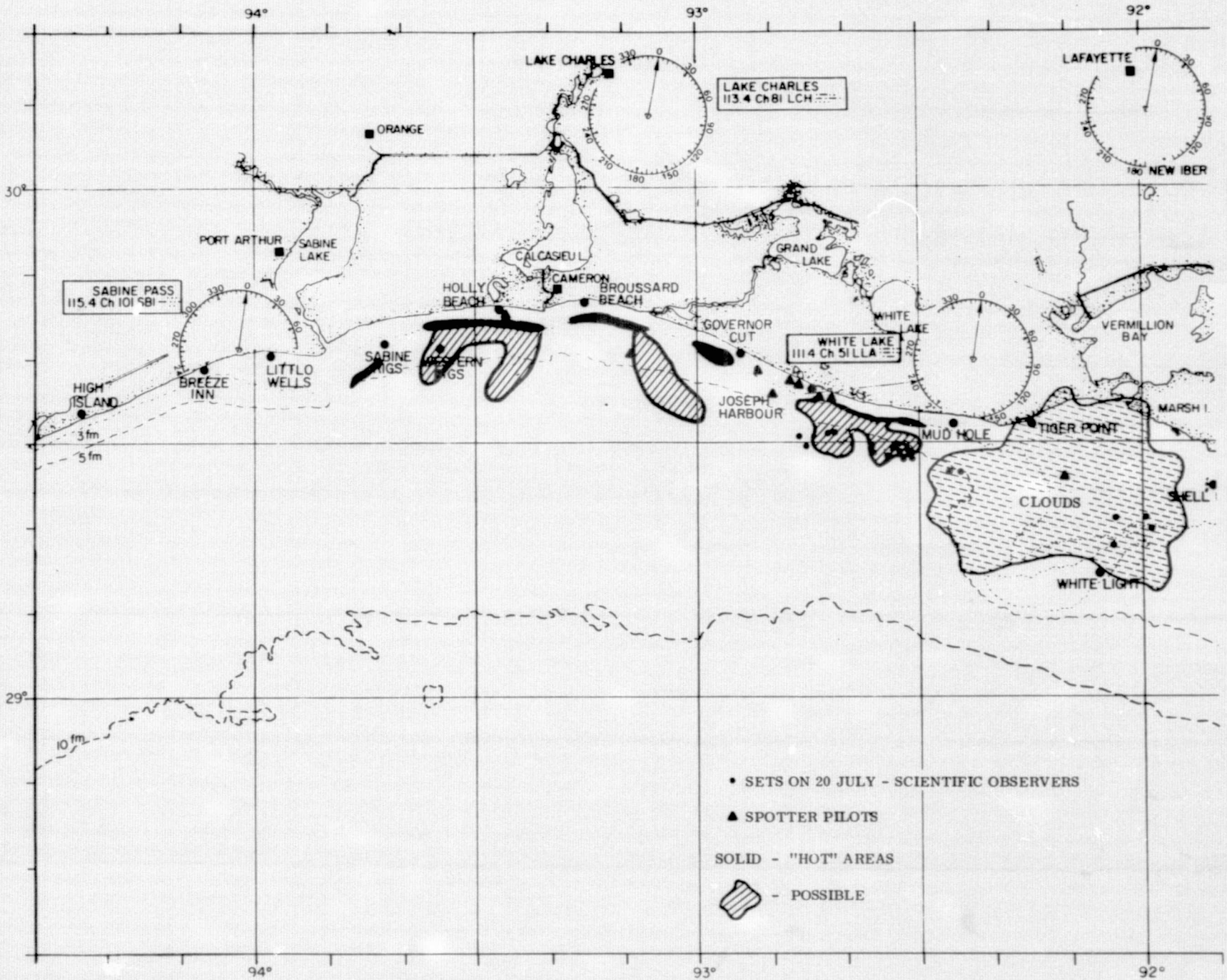


Figure 4.7. Predicted High Probability Fishing Areas for July 20, 1976, Using July 19, 1976, LANDSAT MSS Data.

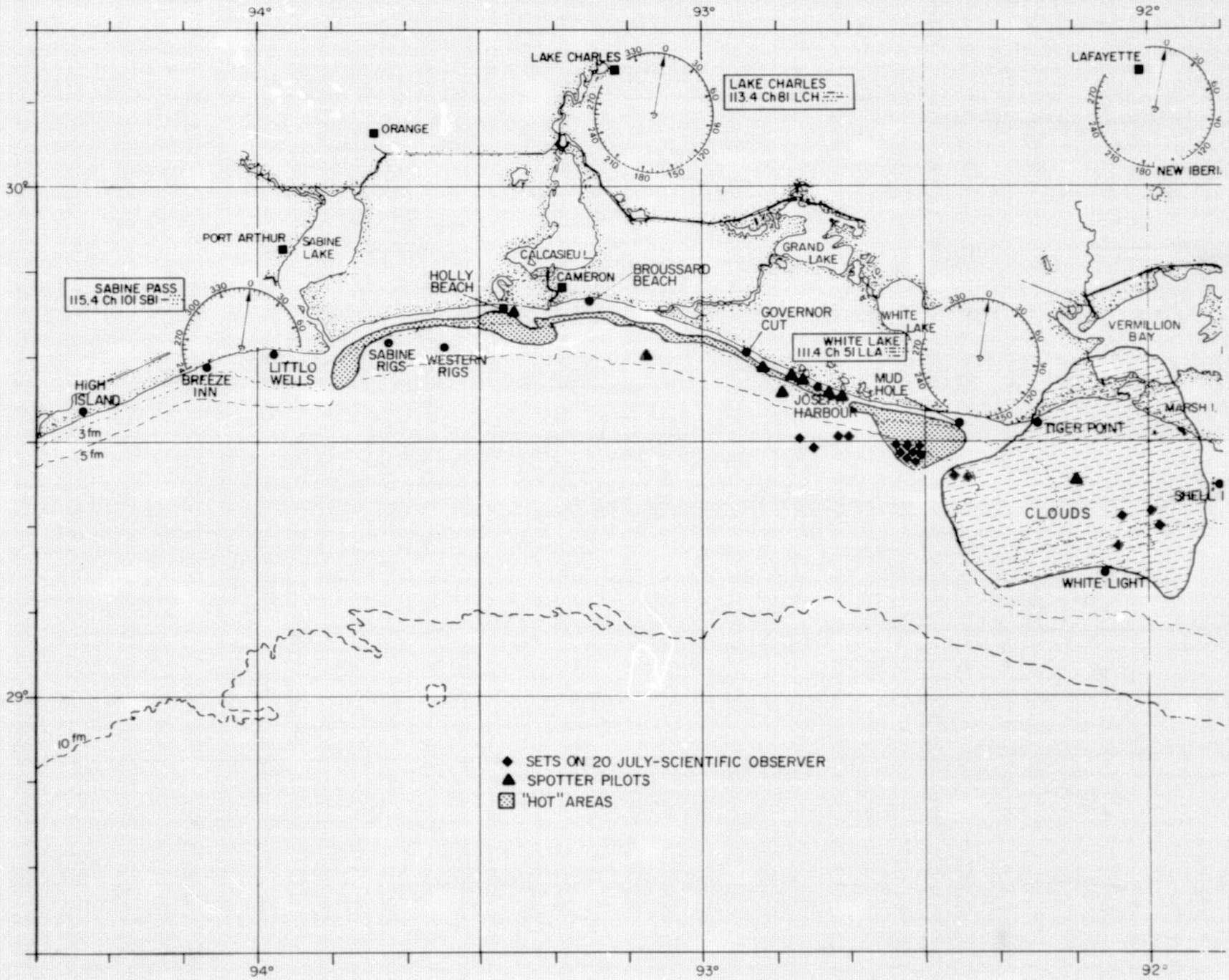


Figure 4.8. Predicted High Probability Fishing Areas for July 20, 1976, Using July 19, 1976, LANDSAT MSS Data With Corrected Fish Location Data.

Table 4.1. Original and Corrected Location and Radiance Values for July 20, 1976, Training Field Data

Original							Corrected					
			Radiance						Radiance			
Sample	Latitude	Longitude	B1	B2	B3	B4	Latitude	Longitude	B1	B2	B3	B4
JC9 1 WY8	29°41'41"	93°20'40"	24.5	14.4	9.2	1.8	29°45'02"	93°16'42"	27.0	15.9	10.3	2.3
JC10 2 WY9	29°42'16"	93°19'06"	24.1	14.2	9.3	1.9	29°45'46"	93°15'04"	29.0	17.2	10.8	2.4
JC12 3 EX1	29°27'24"	92°42'06"	24.6	14.9	10.1	2.2	29°30'30"	92°38'48"	24.5	14.5	9.6	2.1
JC13 4 EX2	29°25'54"	92°39'12"	23.8	13.9	9.4	1.9	29°29'08"	92°35'55"	24.3	14.1	9.4	1.9
JC14 5 EX3	29°25'40"	92°36'36"	24.0	13.9	9.3	1.9	29°28'54"	92°33'08"	24.3	14.1	9.4	2.0

acquired during the contract extension will be worked on to determine the persistence of the high probability areas. More work is planned for analyzing the relationship of LANDSAT radiance data to chlorophyll-a and turbidity data.

5. SIGNIFICANT RESULTS

The most significant achievements realized by this investigation thus far include the successful charting of high probability fishing areas from LANDSAT MSS data and the successful simulation of an operational satellite system to provide tactical information for the commercial harvest of menhaden.

6. REPORTS, PUBLICATIONS, AND MEETINGS

One manuscript was published which was related to the LANDSAT Investigation. The abstract follows:

> Kemmerer, A. J., J. T. Brucks, T. D. Leming, and E. G. Woods. 1976. Remote Sensing for Fishery Applications. Paper presented to the Instrument Society of America International Conference and Exhibit.
>
> > Direct remote sensing techniques will continue to provide valuable fisheries information. Their principal advantage lies in the spatial and temporal coverage they can provide at a fraction of the cost normally associated with the more conventional sampling techniques (e.g., trawls, seines, acoustics, etc). Their principal disadvantage seems to be in their general inability to penetrate very far into the hydrosphere. For the time being, direct remote sensing methods are probably best applied to surface and near surface schooling pelagic fish and large marine mammals (e.g., whales and seals). Indirect remote sensing techniques offer a means to gain a better understanding of our fisheries resources than heretofore possible. The full potential of these techniques, however, is just beginning to be realized. More research in the area of bio-environmental relationships is essential before indirect remote sensing can be expected to achieve even a fraction of this potential. These techniques probably will be more useful for near surface pelagic fishes, at least in the near future. They also will find their primary use for predicting distribution, which in turn can be used to stratify survey designs and enhance fishery operations.

Meetings attended during this reporting period are as follows:

October 13-15, 1976: Fall meeting of the National Fish Meal and Oil Association in Point Clear, Alabama.

October 17-19, 1976: Task force workshop for the development of a menhaden management plan in New Orleans, Louisiana.

October 17-18, 1976: LANDSAT Project Review with NASA personnel at Goddard Space Flight Center, Maryland.

October 20-21, 1976: Gulf States Marine Fisheries Commission Meeting in New Orleans, Louisiana.

7. PROBLEMS

No problems at this time.

8. RECOMMENDATIONS

No recommendations are presented at this time.

9. FUNDS EXPENDED

Purchase orders and other expenditures directly attributable to this investigation total $225,719.

10. LANDSAT DATA

Table 10.1 summarizes LANDSAT 1 and 2 ordered in support of this investigation. These data are being used to establish relationships between the distribution of menhaden and thread herring and their ocean environment as manifested in the LANDSAT spectral channels.

11. AIRCRAFT DATA

Table 11.1 summarizes the status of data acquired with sensors aboard the NP3A. These data were primarily used for computing salinity conditions in the two test sites.

Table 10.1. Summary of LANDSAT Data Status

Mission Date	Satellite	Ident. Code	Data Quality	Value of Data Ordered ($) 9"X9" Transparency		
				Pos.	Neg.	CCT
April 25	I	5006 - 15485	Fair	20	24	200
May 2	II	2100 - 15445	Poor	20	24	-
May 13	I	5024 - 15480	Fair	20	24	-
May 20	II	2118 - 15448	Good	20	24	200
May 21	II	5024 - 15473	Good	20	24	200
June 18	I	?	Not recieved	20	24	-
June 25	II	2154 - 15450	Excellent	20	24	200
July 24	I	5096 - 15435	Good	20	24	200
July 31	II	1290 - 15442	Not received	20	24	-
August 11	I	?	Not received	20	24	-
August 18	II	2208 - 15435	Excellent	20	24	-
August 20	II	2210 - 15554	Poor	20	24	200
Sept 5	II	?	Not received	20	24	-
Sept 16	I	?	Not received	20	24	-
Sept 23	II	?	Not received	20	24	-
July 19 '76	I	5457 - 15255	Excellent	-	-	-
July 27 '76	II	2552 - 15485	Excellent	-	-	-
July 28 '76	II	2553 - 15543	Excellent	-	-	-
July 29 '76	II	2554 - 16001	Excellent	-	-	-
		TOTALS		300	360	1860

Table 11.1. Aircraft Data (NP3A) Status

Mission Date 1975	Microwave		PRT-5		M^2S		Photography (Boresight)	
	Status	Quality	Status	Quality	Status	Quality	Status	Quality
April 25	In lab	Good	In Lab	Good	In lab	Good	In lab	Poor
May 2	In lab	Adequate	In Lab	Adequate	NA	NA	In lab	Poor
May 13	In Lab	Good	In Lab	Good	In lab		In lab	Poor
May 20	In lab	Good	In Lab	Good	NA	NA	In lab	Poor
July 24	NA	NA	NA	NA	NA	NA	NA	NA
July 31	NA	NA	NA	NA	NA	NA	NA	NA
August 20	In Lab	Good	In Lab	Good	In lab	Good	In Lab	Poor
Sept 5	In Lab	Good	In Lab	Good	NA	NA	In Lab	Poor